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Optical disc apparatus

The present invention relates to an optical disc apparatus for recording and/or reproducing information on/from an information surface of a rotatable optical disc. Such an apparatus may comprise a supporting assembly; a motor, associated with the supporting assembly, for rotating the optical disc about a spindle axis; optical means associated with the supporting assembly for scanning an information surface of said optical disc and comprising: a focusing lens assembly having a movable focusing lens having a focusing axis, said focusing lens assembly being movable in a focusing direction for focusing an optical beam on said information surface of said optical disc; a swing arm assembly comprising a generally elongate swing arm structure mounting said focusing lens assembly at a free end, the swing arm assembly being pivotally movable about a swing axis spaced from said free end and directed generally perpendicularly to the swing arm structure and generally parallel to said spindle axis and said focusing axis, such that the swing arm assembly pivotally sweeps a scanning plane generally parallel to said information surface of the mounted optical disc, the swing arm assembly thereby causing said focusing lens assembly to scan over the information surface of the mounted optical disc, the swing arm assembly comprising first pivoting means for enabling focusing movements of said focusing lens assembly and second pivoting means for enabling said pivotal scanning movements of the swing arm assembly and further comprising movable magnetic focusing means provided near said free end of the swing arm assembly for driving said focusing lens along said focusing axis to focus said optical beam on the optical disc information surface, and movable magnetic scanning means for driving said swing arm assembly pivotally about said swing axis for scanning the disc information surface. The optical disc apparatus may further comprise stationary magnetic focusing means associated with the supporting assembly for magnetically cooperating across an intermediate air gap with said movable magnetic focusing means for generating a magnetic force vector having a vector component parallel to said focusing axis for driving the focusing lens assembly along said focusing axis and stationary magnetic scanning means associated with the supporting assembly for magnetically cooperating across an intermediate air gap with said movable magnetic scanning means for generating a magnetic torque about said swing axis for driving the swing arm assembly about said swing axis, the stationary

magnetic focusing means and the stationary magnetic scanning means both being provided near the free end of the swing arm structure.

An optical disc apparatus of this kind is known from US Patent No. 4,794,586. An optical disc apparatus is disclosed having a swing arm assembly in which the movable magnetic focusing means and the movable magnetic scanning means comprise two voice coils arranged at the free end of the swing arm assembly, whose windings are crossed to provide both focusing and scanning movements in cooperation with stationary permanent magnetic stator means. The swing arm assembly is pivotally movable about a swing axis which is the central axis of a stationary pivot. To focus the focusing lens, the arm assembly is flexed as a whole by the magnetic focusing force produced by the voice coils at the free end of the arm assembly.

Flexing the arm assembly as a whole for focusing purposes entails several disadvantages. To withstand the high acceleration and deceleration forces which are produced during scanning, the arm assembly should preferably be rigid in the direction of pivoting. A rigid arm assembly, however, will resist flexing in a direction perpendicular to the pivoting movements. Large focusing forces therefore need to be exerted by the magnetic focusing means. Also, flexing of the swing arm assembly may upset the focusing assembly and associated optical means which need to be accurately aligned under all circumstances.

It is an object of the invention to provide a novel and useful optical disc apparatus which is particularly suitable for miniaturization and which avoids the disadvantages of the prior art apparatus. This object is achieved with the optical disc apparatus as defined in Claim 1. Particularly the apparatus according to the invention has the characterizing feature that the swing arm structure is rigid from the free end up to at least adjacent the swing axis, the first pivoting being provided at or adjacent the second pivoting means.

Thus, the swing arm structure is entirely rigid and does not need to be flexed. The swing arm assembly is thus made eminently suitable for miniaturization, all elements of the optical system that need to be mounted in the swing arm assembly may be mounted in fixed relative positions. The first and second pivoting means may be specialized for their respective functions, resisting movements in any direction but the designed pivoting direction.

In a practical embodiment the optical disc apparatus according to the invention comprises: a supporting assembly; a motor, associated with the supporting assembly, for rotating the optical disc about a spindle axis; optical means associated with the supporting assembly for scanning an information surface of said optical disc and comprising: a focusing lens assembly having a movable focusing lens having a focusing axis, said focusing lens assembly being movable in a focusing direction for focusing an optical beam on said information surface of said optical disc; a swing arm assembly comprising a generally elongate swing arm structure mounting said focusing lens assembly at a free end, the swing arm assembly being pivotally movable about a swing axis spaced from said free end and directed generally perpendicularly to the swing arm structure and generally parallel to said spindle axis and said focusing axis, such that the swing arm assembly pivotally sweeps a scanning plane generally parallel to said information surface of the mounted optical disc, the swing arm assembly thereby causing said focusing lens assembly to scan over the information surface of the mounted optical disc, the swing arm assembly comprising first pivoting means for enabling focusing movements of said focusing lens assembly and second pivoting means for enabling said pivotal scanning movements of the swing arm assembly and further comprising movable magnetic focusing means provided near said free end of the swing arm assembly for driving said focusing lens along said focusing axis to focus said optical beam on the optical disc information surface, and movable magnetic scanning means for driving said swing arm assembly pivotally about said swing axis for scanning the disc information surface. The optical disc apparatus may further comprise stationary magnetic focusing means associated with the supporting assembly for magnetically cooperating across an intermediate air gap with said movable magnetic focusing means for generating a magnetic force vector (F; P) having a vector component parallel to said focusing axis for driving the focusing lens assembly along said focusing axis and stationary magnetic scanning means associated with the supporting assembly for magnetically cooperating across an intermediate air gap with said movable magnetic scanning means for generating a magnetic torque about said swing axis for driving the swing arm assembly about said swing axis, wherein:

- the swing arm structure is rigid from the free end up to at least adjacent the swing axis, and
- the first pivoting means are provided at or adjacent the second pivoting means.

The objects and features of the present invention will become more apparent by referring to the following non-limiting description of a preferred embodiment given with reference to the accompanying drawings, in which:

Fig. 1 is a schematic plan view of an optical disc apparatus of miniaturized dimensions,

Fig. 2 is a schematic perspective fragmentary view of the optical disc apparatus of Fig.1,

Figs. 3 to 5 are plan views of individual stator laminations of the combined motor and focussing/scanning stator of the optical disc apparatus of Figs. 1 to 2,

Fig. 6 is a side view of a stack of stator laminations shown individually in Figs. 3 to 5,

Fig. 7 is a perspective view of the stacked stator laminations from Fig. 6,

Fig. 8 is a fragmentary plan view illustrating alternative biasing means for biasing a swing arm structure magnetically away from a spindle motor stator,

Fig. 9 is a block diagram of the electronic circuitry for the coarse and fine control of the rigid swing arm focusing and scanning positions,

Fig. 10 is a schematic perspective view similar to Fig. 2 but of an alternative embodiment of an optical disc apparatus,

Fig. 11 is a perspective exploded view of the arrangement of electrical coils used to control the rigid swing arm scanning and focusing movements of the optical disc apparatus of Fig. 10,

Fig. 12 is a fragmentary schematic side elevational view of a further embodiment of an optical disc apparatus in accordance with the present invention,

Fig. 13 is a fragmentary plan view of the optical disc apparatus of Fig. 12, and

Fig. 14 is a fragmentary side elevation of a detail of Fig. 12 on an enlarged scale.

Referring to Figs. 1 and 2 of the drawing, an optical disc apparatus 1 is shown for recording and/or reproducing information on/from an information surface 3 of a rotatable optical disc 5. The optical disc apparatus 1 is of miniaturized dimensions and is shown in Fig. 1 to approximately true scale. The optical disc has a diameter of the order of 23 mm.

The optical disc apparatus 1 comprises a supporting assembly 7 which in the embodiment shown is a printed circuit board measuring some 30 x 40 mm. A spindle motor 9

is associated with the supporting assembly 7 and has a spindle 11 with a spindle axis 13 for rotating the optical disc 5 mounted on the spindle 11 about the spindle axis 13. The spindle motor 9 comprises a permanent magnetic rotor 15 and a magnetic motor stator 17, magnetically cooperating with each other across an intermediate air gap 19.

Optical means are associated with the supporting assembly 7 for scanning the information surface 3 of the optical disc 1 mounted on the spindle 11. The optical means comprise a diode laser unit 21, a beam splitter 23, a collimator lens 25, a 90^0 reflecting element 27, a focusing lens assembly 29 comprising a lens mount 31 and a movable focusing lens 33 having a focusing axis 35, the focusing lens assembly 29 being movable in an axial direction along the focusing axis 35. The optical means further comprise a so-called servo lens 37 and a photosensitive array 39. All these optical elements are well known to those skilled in the art of optical disc equipment and will not be explained in detail here. The photodiode laser unit 21 emits a laser beam 42 which is split by the beam splitter 33. Part of the beam is directed to the 90^0 reflecting element 27 and is shaped by the collimator lens. The laser beam is reflected by the 90^0 reflecting element 27 and projected through the focusing lens 33 onto the information surface 3 of the optical disc 5. The beam modulated by the data present in the rotating disc 5 is reflected by the information surface 3 and returns through the focusing lens 33, is reflected by the 90^0 reflecting element 27, passes through the collimator lens 25 and at least partly through the beam splitter 23, and impinges on the photosensitive array 29. The output signals of the photosensitive array 29 are output to electronics circuits to derive the data signals representing the data read out from the information surface 3 of the optical disc 5 and to extract the error signals needed to control the position and the movements of the optical assembly relative to the information surface 3 of the optical disc 5.

The optical assembly 21-39 described above is provided in a swing arm assembly 41 comprising a generally elongate swing arm structure 43 mounting said focusing lens assembly 31-33 near a free end 45, the swing arm assembly 41 being pivotally rotationally movable about a swing axis 47 remote from said free end 45 and directed generally perpendicularly to the swing arm structure 42 and generally parallel to said spindle axis 13 and said focusing axis 35, such that the swing arm assembly 41 rotationally sweeps a scanning plane generally parallel to said information surface 3 of the mounted optical disc 5, the swing arm assembly thereby causing said focusing lens assembly 31-33 to scan over the information surface 3 of the mounted optical disc 5.

Rotational pivoting means 49-53 are provided for enabling said rotational scanning movements of the swing arm assembly 41, which means comprise stationary

pivoting means 49 associated with the supporting assembly 7 and movable pivoting means 51 associated with the swing arm structure 43 pivotally cooperating with the stationary pivoting means 51. In the present embodiment, the stationary pivoting means 49 and the rotational pivoting means 51 are permanently connected to each other by a deflectable leaf spring 53, which allows pivoting movements of the swing arm assembly 41 in the scanning direction parallel to the information surface 3 of the optical disc 5 only.

Movable magnetic scanning means 55-57 are provided at the free end of the swing arm assembly 41 for driving the swing arm assembly rotationally about its swing axis 47. In the present embodiment, the movable magnetic scanning means comprise two adjacent permanent magnets 55 and 57 which have been fixed on the free end of the swing arm structure 43 by suitable means such as an adhesive. The permanent magnets 55,57 are magnetized in parallel opposite directions (indicated by arrows in Fig. 2) basically along a magnetic axis parallel to the general extension of the swing arm assembly 41.

Stationary magnetic scanning means are provided, associated with the supporting assembly 7 and comprising a magnetic scanning stator core 59 provided near and spaced away from the free end of the swing arm assembly 41 for magnetically cooperating with the movable magnetic scanning means 55,57 across an intermediate air gap 61 disposed in a curved plane 63 (see more particularly Fig. 3, which will be discussed below).

The embodiment of the invention shown in Figs. 1-2 is of a kind in which the pivoting means 49-51 discussed above for enabling scanning movements of the swing arm assembly are second pivoting means, first pivoting means being provided for enabling focusing movements of said focusing lens assembly 29. These first pivoting means resemble the already discussed second pivoting means in that they comprise a leaf spring 65 which is fixed to an end part 67 of the swing arm structure 43 on one side and to the movable pivoting means 51. The movable pivoting means 51 thus form an intermediate element between the two leaf springs 53 and 65. The leaf spring 65 is oriented such that it will allow movements of swing arm structure 41 whereby the focusing lens 33 can move along the focusing axis 35 only.

The movable magnetic scanning means 55-57 also operate as movable magnetic focusing means provided near the said free end 45 of the swing arm assembly 41 for driving the focusing lens 33 along the focusing axis 35 to focus the optical beam 42 on the optical disc information surface 3 and thus form combined movable magnetic focusing/scanning means 55-57. Stationary magnetic focusing means are present, associated with the supporting assembly 7 for magnetically cooperating across the intermediate air gap

61 with the said combined movable magnetic focusing/scanning means 55-57 for generating a magnetic force vector having a vector component F parallel to the focusing axis 35 for driving the focusing lens assembly 29 along the focusing axis 35. These stationary magnetic focusing means are combined with the stationary magnetic scanning means and will be discussed below in connection with Figs. 2-8.

The swing arm structure 43 is rigid from the free end 45 up to at least adjacent the swing axis 47, and the first pivoting means 51, 65, 67 are provided at or adjacent the second pivoting means 49, 51, 53. The swing arm structure 43 is shown more particularly in Fig. 2 as a box-like structure housing the optical means 21-33, the lens mount 31 being a fixed element rigidly connected to the swing arm structure 43. However, alternative solutions may suggest themselves to those skilled in the art. The swing arm structure could, for example, be shaped as a rigid profiled beam carrying the optical means 21-33 on the outside. Part of the optical means could be located outside the swing arm structure and communicate with the remaining means present on or in the swing arm structure through optical, electrical, or other connections. The swing arm structure of the optical disc apparatus 1 of Figs. 1-2 has very small dimensions of the order of 2x2x16 mm.

A feature of the embodiment of the invention shown in Figs. 1-2, which is the subject matter of a co-pending application PHNL020897 (Applicant's identification number), having the same priority date as the present application and which is herewith incorporated in the present application by reference, is that the stationary magnetic scanning means or magnetic scanning stator core 59 is rigidly associated with the magnetic motor stator 17. In fact, in the embodiment of Figs. 1-2, the motor stator 17 and the scanning stator core 59 are integrated into a combined stationary unit. Also, the stationary pivoting means 49 are rigidly associated with the magnetic motor stator 17. In fact, the motor stator 17, the scanning stator core 59, and the stationary pivoting means 49 are all integrated into a combined stationary unit. As was noted above for the embodiment according to Figs. 1-2, the stationary magnetic focusing means are combined with the stationary magnetic scanning means, so that in Figs. 1-2 the motor stator, the scanning stator core, the stationary pivoting means, and a focusing stator core are all integrated into a combined stationary unit.

Referring now more particularly to Figs. 3-6, the combined stationary unit comprises a stator packet assembled from magnetizable individual stator laminations of three different kinds referenced 69, 71 and 73, respectively. In the embodiment of the invention according to Figs. 1-2, the movable magnetic scanning means comprise permanent magnetic rotationally movable scanning means 55,57, and the stationary magnetic scanning means

comprise a number of individual stator coils 75 (six coils) arranged on the stator core 59 in a serial arrangement along the rotational scanning path of the movable permanent magnetic scanning means 55,57. Electronic commutating means are provided (to be discussed later) to selectively switch individual stator coils 75 on and off, scanning sensor means 79 (five sensors) being provided for detecting and scanning control means (to be discussed later) which are provided for controlling the rotational position of the arm structure 43 by controlling the current amplitude and direction in each of the stator coils 75 that have been selectively switched on in order to control the rotational arm position and movements.

In the embodiment of the invention according to Figs. 1-2, the movable magnetic focusing means comprise permanent magnetic axially movable focusing means also formed by the permanent magnets 55,57, the stationary magnetic scanning means, and the stationary magnetic focusing means comprising a number of individual stator coils 75 (six coils) and 77 (six coils) arranged on the stator core in a serial arrangement along the rotational scanning path of the movable permanent magnetic scanning means 55,57 and distributed over two axially spaced levels. Focusing sensor means are provided in the photosensitive array 39 for detecting the focusing position of the focusing lens 33 in the usual way. Focusing control means and scanning control means (to be discussed later on) are provided for controlling the axial focusing lens 33 position and the angular position of the swing arm assembly 41, respectively, by controlling the current amplitude and direction in each of the stator coils 75,77 that have been selectively switched on in order to control the axial focusing lens position and movements. The stator coils 75,77 in each of the two levels are spaced at a constant pitch on the stator core 59 along the path rotationally swept by the movable magnetic scanning means and movable magnetic focusing means 55,57. The stator coils 75,77 in the two levels are arranged in planes parallel to the scanning plane of the scanning arm structure and the stator coils 75 present in one level are positioned between the stator coils 77 present in the other level.

Figs. 3-6 illustrate how both the motor stator core 17 of the spindle motor 9 and the scanning stator core 59 of the stationary magnetic scanning/focusing means may be assembled from individual stator laminations 69, 71 and 73. As is customary, the stator laminations consist of individual parts stamped from soft iron plate material, covered on both sides with an electrically insulating coating or film to prevent eddy currents from flowing between the individual laminations. Each of the laminations 69-73 is provided with an annular portion 81 provided with inwardly projecting, angularly evenly spaced teeth. Stator plates 69 are provided with a curved portion 85 extending from and integral with the annular

part 81 and provided with mutually evenly spaced teeth 87. Stator plates 73 are similarly configured with a curved portion 89 having teeth 91 in positions offset from the teeth 87 but having the same mutual spacing or pitch.

Stator plates 73 are provided with a curved portion 93 configured similarly to the curved portions 85 and 89, but without teeth. The combined spindle motor/scanning stator is assembled by stacking, for example, six of the laminations 69 on three laminations 71 on six laminations 73, the teeth 83, 87 and 91 thus forming eight stator teeth 95 for eight motor stator coils 97, as well as six teeth for the six coils 75 and six teeth for the six coils 77 for the scanning stator core 59, respectively. The axial separation of the two rows of coils 75,77 is provided by the intermediate laminations 93.

Biasing means 99 formed by a small permanent magnet are provided to bias the magnetic attraction force produced between the movable permanent magnetic scanning/focusing means 55,57 and the motor stator 17, whereby magnetic adhesion of the scanning arm structure 43 to the motor stator 17 is prevented in a rotationally extreme position of the scanning arm structure 43 nearest to the spindle motor 9. The magnetic field of the permanent magnet 99 interacts with the magnetic fields of the permanent magnets 55,57 in a repellant way such that the scanning arm structure 43 will be prevented from adhering magnetically to the spindle motor 9.

In the optical disc apparatus 1 according to the embodiment of Figs. 1-2, the motor stator 17, the scanning/focusing stator core 59, as well as the stationary pivoting means 49 are all integrated into a combined stationary unit. Referring now more particularly to Figs. 3-7, the laminations 71 are for this purpose provided with a further extension 101 at the free end of the curved portion 93 and at an appropriate angle to the curved portion 93 of, for example, approximately 90^0. The stacked extensions 101 of the laminations 71 form a supporting beam, while the stacked laminations 69 and 73 form the mutually offset stator teeth 105 and 107, respectively, of the scanning stator core 59. The method of securing the leaf springs 53 and 65 between the swing arm structure 43 and the rotating pivoting means 51 and between the pivoting means 51 and the stationary pivoting means 49 at the free end of the supporting beam 103, respectively, has been shown schematically only in Figs. 1-2. The leaf springs may be secured by any of a variety of methods known to those skilled in the art, such as by adhesive means, laser welding, spot welding, mechanical clamping, by screws or rivets, etc.

Fig. 8 is illustrative of an embodiment of the invention which has been slightly modified in comparison with the embodiment of Figs. 1-7. Only those details will be

discussed which are typical of this modified embodiment. The biasing means 99 are no longer required in this modified embodiment. Instead, the biasing means are provided by one or more stator teeth 105,107 on the scanning stator core 59, positioned in such a way that in said extreme rotational position of the scanning arm structure 43 the rotational magnetic pull of said one or more stator teeth 105,107 exerted on the rotating permanent magnetic scanning means 55,57 exceeds the rotational magnetic pull of the motor stator 17. This is accomplished by widening the air gap 61 between stator teeth 55,57 and the rotating permanent magnetic scanning means 55,57 in the vicinity of the motor stator 17. As a result, the magnetic pull P exerted by the stator teeth 55,57 will exceed the magnetic pull of the motor stator 17 in any position of the swing arm structure 43.

Referring now to the block diagram of Fig. 9, the electronic coarse and fine control of the rigid swing arm angular and focusing positions will be briefly discussed. The five magnetic field sensors 79, for example of the Hall sensor type or any other suitable type, sense the magnetic fields of the movable permanent magnetic scanning/focusing means 55,57 and produce electrical magnetic field signals 109 representative of the magnetic field strength and direction sensed. The five signals 109 are input to a magnetic field signal processing unit 111 in which the swing arm angular and focusing position is determined. From this unit a swing arm position signal is output which is input to a coil selection and polarity unit 115. Also input to the coil selection and polarity unit are a focus control signal and tracking control signal 119. These signals are derived from the focus control and tracking control signals provided by the control circuitry (not shown) connected to the photosensitive array 39 which may be largely conventional. The focus control and tracking control signals are used for a fine tuning of the position of the laser beam spot produced by the focusing lens 33 relative to a track of the information surface 3 of the optical disc 5 of the optical disc apparatus 1. The coil selection and polarity unit 115 has twelve outputs 121, each connected to a respective one of the twelve coils 75, 77 of the stationary magnetic scanning means. The operation of the coil selection and polarity unit during normal operation of the optical disc apparatus 1 is such that only those coils are selected that are actively needed for the fine control of the swing arm position with respect to the nominal current position of the swing arm with respect to the tracks in the information surface 3 of the optical disc sensed by the magnetic field sensors 79. Only a selected few of the outputs 121 are switched on in any such nominal current position. These outputs are controlled by the coil selection and polarity unit in amplitude and polarity in a way suitable for achieving the necessary fine focusing and tracking control. The twelve outputs 121 from the coil selection and polarity unit are

connected to twelve corresponding inputs of twelve coil driving circuits provided in a coil driving unit 123, which coil driving circuits amplify the output signals of the coil selection and polarity unit to a level suitable for generating the required magnetic fields in each of the selected coils 75,77 which are active in the current arm position.

Different embodiments may be used with the invention. Referring now to Fig. 10, an embodiment will be described comprising an optical disc apparatus 125 with an optical disc having an information surface 129 and further comprising a supporting assembly 131. The dimensions may be similar to those of Figs. 1-7, while a number of constituent parts are also similar and will therefore not be described in detail. A spindle motor 133 is provided for rotating the optical disc 127. A swing arm assembly 135 comprises a swing arm structure 137 comprising a number of optical components, such as the swing arm assembly 41 of Fig. 2, among them a focusing lens 139 mounted on a lens mount 141. The focusing lens 139 is movable along a focusing axis 143, and the swing arm assembly is pivotable about a swing axis 145 parallel to the focusing axis 143. Leaf springs 147 and 149 are provided for enabling pivoting focusing and scanning movements of the entire rigid swing arm structure 137 relative to an intermediate part 151 and stationary pivoting means 153, respectively. The movable magnetic scanning means comprise a cylindrical scanning coil 155 having a generally rectangular shape in cross-section and having a central opening 157, two pairs of parallel outer side surfaces 159, 161 and 163, 165, two pairs of inner side surfaces 167, 169 and 171, 173, and outwardly facing axial end surfaces 175, 177, respectively, at the axially spaced ends of the coil. The movable focusing means comprising two substantially identical cylindrical focusing coils 179A, 179B having a generally rectangular shape in cross-section and having a central opening 181, two pairs of parallel outer side surfaces 183, 185 and 187, 189, two pairs of inner side surfaces 191, 193 and 195, 197, and outwardly facing axial end surfaces 199, 201, respectively, at the axially spaced ends of the coil. The scanning coil 155 is bonded with its outer side surface 159 against the free end 203 of the swing arm structure 137 in a position with its central axis 205 generally parallel to the scanning movements of the swing arm assembly 135 by suitable means such as adhesive means. Each focusing coil 179A,B is being bonded at a portion of its outwardly facing axial end surface 199 at one side of its central opening 181 against the outer side surface 161 of the scanning coil 155 remote from the swing arm structure 137 by suitable bonding means such as adhesive means, the two focusing coils 179A,B being disposed such that said portions of their outward facing axial end surfaces 199 are near to each other, parallel to each other, and generally parallel to the scanning movements of the swing arm assembly 135. Combined stationary magnetic means

comprise an elongate permanent magnet means 207 facing the movable focusing coils 179A,B and spaced from the focusing coils 179A,B by an air gap, and further comprising a magnetically permeable stator 209 supporting the permanent magnetic means 207 and having a stator part 211 passing through the central opening 157 of the scanning coil 155 with clearance, the permanent magnet means 207 being magnetically polarized in a radial direction relative to the swing axis 145 of the swing arm assembly 135, and the arrangement being such that a substantially radially directed permanent magnetic field is set up across the air gaps present between the scanning coil and the stator part 211 and between said parts of the focusing coils 179A,B and the stator 209. In accordance with the invention, the stationary magnetic scanning means 207-211 are rigidly associated with the magnetic motor stator of the spindle motor 133. In accordance with a further feature of the invention, the motor stator of the spindle motor 133, the scanning stator core part 211, the stationary pivoting means 153, and the focusing stator core 209 are integrated into a combined stationary unit. This stationary unit is made from a suitable magnetically permeable material such as soft iron and comprises a temporarily removable part, the part 211, to enable insertion into the central opening 157 of the scanning coil 155. The stationary unit is provided with a supporting beam part having the same thickness as the remaining parts of the stationary unit 209, 211, 213 carrying the stationary pivoting means 153 at its free end and may be formed by a stack of stator laminations which may be integrated with the motor stator of the spindle motor 133.

A third embodiment of the present invention will be discussed with reference to Figs. 12-14. The optical disc apparatus 215 of Figs. 12-14 for recording and/or reproducing information on/from an information surface 217 of a rotatable optical disc 219 comprises a supporting assembly 221, and a spindle motor 223 associated with the supporting assembly 221 having a spindle 225 with a spindle axis 227 for rotating the optical disc 219 mounted on the spindle 225 about the spindle axis 227. Optical means are associated with the supporting assembly 221 for scanning the information surface 217 of the optical disc 219 mounted on the spindle 225 and comprise a focusing lens assembly 229 having a movable focusing lens 231 having a focusing axis 233, the focusing lens assembly 229 being movable in a focusing direction for focusing an optical beam 235 on the information surface 217 of the optical disc 219. A swing arm assembly 237 is provided, comprising a generally elongate swing arm structure 239 supporting the focusing lens assembly 229 at a free end 241, the swing arm assembly 237 being pivotally movable about a swing axis 243 spaced from the free end 241 and directed generally perpendicularly to the swing arm structure 239 and generally parallel to the spindle axis 227 and the focusing axis 233, such that the swing arm

assembly 237 pivotally sweeps a scanning plane generally parallel to the information surface 217 of the mounted optical disc 219, the swing arm assembly 237 thereby causing the focusing lens assembly 229 to scan over the information surface 217 of the mounted optical disc 219. The swing arm assembly 237 comprises a swing arm structure 239 extending from the free end 241 up to at least adjacent the swing axis 243, first pivoting means being provided for enabling focusing movements of the focusing lens assembly 229 and second pivoting means being provided for enabling the pivotal scanning movements of the swing arm assembly 237. Movable magnetic focusing means 245 are provided near the free end 241 of the swing arm assembly 237 having the form of a flat coil for driving the focusing lens 231 along the focusing axis 233 to focus the optical beam 235 on the optical disc information surface 217, and movable magnetic scanning means 247 are provided for driving the swing arm assembly 237 pivotally about the swing axis 243 for scanning the disc information surface 217. The optical disc apparatus 215 further comprises stationary magnetic focusing means 249 associated with the supporting assembly 221 for magnetically cooperating across an intermediate air gap 251 with the movable magnetic focusing means 245 for generating a magnetic force vector P having a vector component parallel to the focusing axis 233 for driving the focusing lens assembly 229 along the focusing axis 233, and stationary magnetic scanning means 253 are provided (shown schematically only in ghost lines in Figs. 12-13) associated with the supporting assembly 221 for magnetically cooperating across an intermediate air gap with the movable magnetic scanning means 247 for generating a magnetic torque about the swing axis 243 for driving the swing arm assembly 237 about the swing axis 243, in the present embodiment the stationary magnetic focusing means 249 and the stationary magnetic scanning means 253 being provided at opposite ends of the swing arm structure 239. The swing arm structure 239 is rigid from the free end 241 up to adjacent the swing axis 243, and the first pivoting means are provided at or adjacent the second pivoting means.

The optical means, the swing arm assembly 237, and the first and second pivoting means will now be described in more detail with reference to Figs. 12-14.

As in the previous embodiments, the optical means for reading and/or writing information from/on the information surface 217 of the optical disc 219 may comprise a number of optical elements similar to the optical elements 21, 23, 25, 37, and 39 in addition to the focusing lens assembly 229. This focusing lens assembly is constituted of an integrated unit manufactured to high precision from an optical-grade transparent plastics comprising the focusing lens 231 as well as a 90^0 internally reflecting surface 255 (Fig. 14). All these optical

elements may be housed within the swing arm structure 239 which in the embodiment illustrated in Figs. 12-14 has a hollow box-shaped configuration, but could be of any suitable rigid configuration depending on design choice. Also, as before, part of the optical and/or electronic components needed for reading and/or writing information on/from the optical disc 219 may be disposed elsewhere on the supporting structure 221 and connected by suitable optical and/or electrical connections to the focusing lens assembly 229 and other associated elements.

The swing arm assembly is formed by two mutually pivotally movable parts: the rigid swing arm structure 239 and a driving structure 257 comprising a pivoting rigid frame element 259 supporting at its free end 261 the movable magnetic scanning means 247 configured as a generally flat scanning coil of the general shape shown in Fig. 13. The scanning coil cooperates magnetically with stationary magnetic scanning means configured as a permanent yoke structure known *per se* from the art of optical and magnetic disc drive devices, secured on the supporting structure 221 and only outlined by ghost lines in Figs. 12,13 for the sake of simplicity.

Near its end 263 opposite to its free end 261, the frame element 259 is pivotally movable about a stationary pivot pin 265 having a centerline coinciding with the swing axis 243 generally parallel to the spindle axis 227 and the focusing axis 233, which pivot pin 265 is rigidly secured to a bottom plate 267 of the supporting assembly 221. The pivot pin 265 is passed through movable pivoting means 269 secured to the frame element 259 such that the combination of the stationary pivot pin 265 and the movable pivoting means 269 constitute the second pivoting means for enabling pivoting scanning movements of the swing arm assembly 237. At its end 271 opposite to its free end 241, the swing arm structure 239 is provided with two opposite extensions 273 forming the prongs of a two-pronged fork accommodating the end 263 of the frame element 259 and the movable scanning pivoting means 269. Coaxial pivot studs 275A,B are provided on both sides of the movable pivoting means 269 defining a common focusing pivot axis 277 and traversing complementary bores provided in the extensions 273A and 273B. The combination of the pivoting studs and the extensions 273A,B with said complementary bores thus provide the first pivoting means for enabling pivoting focusing movements of the rigid swing arm structure 239 relative to the frame element 259.

The swing arm assembly 237 comprises movable magnetic focusing means 229 near the free end 241 for electromagnetically driving the focusing lens 231 along the focusing axis 233 to focus the optical beam 235 on the optical disc information surface 217.

In the present embodiment, the moving magnetic focusing means consist of a generally annular focussing coil 245 of windings of conductive wire, such as copper wire, in a manner which is known *per se*. The focusing coil 245 may have a generally oval or rectangular shape such as is well known in the art and is shown in cross-section in Fig. 14.

The optical disc apparatus 215 further comprises stationary magnetic focusing means 249 associated with the supporting assembly 221 for magnetically cooperating across an intermediate air gap 251 with the movable focusing means 245 for generating a magnetic force vector having a vector component P which is parallel to the focusing axis 233 for driving the focusing lens assembly 229 along the focusing axis 233. In the present embodiment, the stationary magnetic focusing means consist of a vertically magnetized permanent magnet 279 bounded by ferromagnetic flux concentrating upper and lower yoke plates 281 and 283 mounted an a lower support of suitable magnetically isolating material in a manner well known in the art. The stationary and movable magnetic focusing means 249 and 229, respectively, are disposed such and cooperate such that the force vector component P generally coincides with the focusing axis 233 of the focusing lens 231.

The optical lens assembly 229 comprises a perpendicularly reflecting optical element 255 near the free end 241 of the swing arm structure 239, which element is connected to the focusing lens 231 and in the present embodiment is integral therewith, manufactured from an optical-grade transparent synthetic resin material as an integral optical component having a reflecting surface 255 on one side which reflects the optical beam 235 by total inner reflection. This reflective surface 255 is disposed on the side of the focusing lens 231 which is directed away from the information surface 217 of a mounted optical disc 219 and causes reflection of the laser beam 231 travelling in the general direction between the swing axis 243 and the focusing axis 233 so as to pass through the focusing lens 231 generally along the focusing axis 233. The movable magnetic focusing means 245 are connected to the reflecting element 255 in a position on the side of the reflecting surface 255 directed away from the movable focussing lens 231. The movable and stationary magnetic focusing means 245 and 249, respectively, cooperate across an air gap 251 which is generally parallel to the reflecting surface 255. In fact, the focusing coil 245 is fixed to the outer surface of the reflecting element 255 by means of a suitable adhesive material which will not deteriorate the inner reflective properties of the reflective surface 255. Preferably, the reflecting surface 255 is optically isolated by a suitable material such as a metal layer deposited by vacuum deposition. The reflecting surface 255 of the focusing lens assembly 229 is disposed in an inclined plane relative to the swing axis 243 of the swing arm assembly

237. The movable electrical magnetic coil means 245 are disposed generally in an inclined plane parallel to the reflecting surface 255, and the stationary magnetic focusing means 249 comprise an inclined face 287 directed to the movable electrical magnetic focusing coil means 245 such that the air gap 251 between the movable electrical magnetic focusing coil means 245 and the stationary magnetic focusing means 249 is disposed in an inclined plane generally parallel to the inclined reflective surface 255 of the focusing lens assembly 229.

Three embodiments of optical disc apparatus 1, 125 and 215 according to the invention have been described above, but it will be appreciated by those persons skilled in the art that the invention is not limited by what has been particularly described and shown above. Many modifications are possible without departing from the inventive concepts herein, all comprising the main feature of the invention, which is that the swing arm structure is rigid from the free end up to at least adjacent the swing axis and the first pivoting means are provided at or near the second pivoting means.